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Study of Insect Proof Plywood by Mixing Chlordane with the Glue

Koichi NISHIMOTO*

Abstract——Methods of manufacturing insect proof plywood was investigated by mixing the insecticide with glue. Chlordane was selected as the insecticide because of its standardized quality, availability of quantitative analysis and relatively low mammalian toxicity.

From the result of quantitative analysis, it was demonstrated that plywood with urea resin glue was the highest for the retention of chlordane, followed by those with melamine and phenol resins. Bio-assay for insecticidae effect was made in surface, sub-surface, glue-line and center of each plywood, using adult of *Tribolium castaneum* HERBST as the substitute organism for *Lyctus*-beetle. The effect was higher in melamine-glued plywood than urea- and phenol-glued ones.

Effective does of chlordane in each layer of the plywood, although a slight difference was found depending upon the type of resin used, was 600 g/m^3 on the glue-line, 800 g/m^3 on the center face and 1000 g/m^3 on the sub-surface. For a long residual effect, 900 to 1000 g/m^3 was required for glue-line mixture.

Introduction

Since odorless plywood has been established in the market, damage of the plywood by insects has drastically increased to such an extent that the Ministry of Agriculture and Forestry is compelled to implement necessary regulations and measures to prevent it. There are several methods of manufacturing insect proof plywood; namely chemical treatment of veneers, dipping of finished plywood and glue-line mixture, in which the last method is considered to be most desirable from both technical and economical standpoints because no alteration or addition of manufacturing process is needed.

In general, the term "Insect proofiing of wood" implies the protection of wood from infestation by all insects, so that prevention of damage by both drywood insects such as Lyctidae, Bostrichidae, Anobiidae and Cerambycidae, and termite is included. However, in respect to the environment and the species of wood favorable to insect attack, there is quite a difference between drywood insects and termite. Inasmuch as the majority of wood used for manufacturing plywood is tropical hardwood which is very susceptible to *Lyctus* infestation, it is not improper to exclude termite as a target insect from insect proofiing of plywood. While judging from the habit of *Lyctus* beetle, it is not necessary to treat heartwood with insecticides, it is still best to impart insect proofing to the entire plywood, as it is difficult to distinguish the sapwood portion from the heartwood in the plywood.

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Along the line of above thinking, the author established the policy of study to manufacture insect proof plywood by mixing the insecticide with glue. In this study only chlordane was selected as the insecticide because of its standardized quality, availability of quantitative and qualitative analytical methods and relatively low mammalian toxicity.

In case of glue mixture, the most critical point of consideration is whether or not the insecticide incorporated into the glue may spread out into the surface layer and the core of the plywood. Two types of infestation should be considered in respect to plywood damage caused by *Lyctus*. One type is that hatched larvae feed through the interior of the plywood, and the other type is that, as seen quite often in case of furniture and ceiling, the adult after having fed on the cross-pieces makes shot-holes through the surface of the plywood as emergency exit. The former type of damage is very important in the sense that strength and quality of the plywood itself are destroyed. Prevention of this type of damage can be achieved by sufficient absorption of the insecticide in the plywood so that hatched larvae are immediately killed by either contact or stomach poison. In the latter case, while it does not give structural damage to the plywood, its appearance is adversely affected. In this case, whether or not above type of treatment is sufficient to prevent the damage is questionable, because the adult grown in the cross-piece is more tolerant to the insecticide than newly hatched larvae and that vertical tunnelling through the plywood with the purpose of making exit hole without feeding only allows a short time of contact with the insecticide. In order to stop the latter type of damage perfectly, surface treatment with an insecticide having either fast knock-down effect or repellent action may be the only procedure. No such insecticide being available in the market, heavy coating with commercially available insecticides on the surface is the second best method of protection. However, this method is impracticable in necessity of an extra process and additional drying process.

Under the present circumstances, the method of incorporating the insecticide into the glue is considered to be an effective procedure to stop the former type of damage, and to reduce the latter type of damage although perfect protection cannot be expected. It is necessary to establish a standard method of treatment by determining the extent of insecticide diffusion in each layer of the plywood and its amount captured in the glue-line, and by checking if 800 g/m^3 dosage is sufficient from the standpoint of efficacy.

Materials and Methods

1. Formula of glue

(1) Urea:

Sample code	UA	UB	UC
Oshika resin 210	100 parts	100 parts	100 parts
Wheat flour	25	25	25
Water	10	10	10
NH_4Cl	0.5	0.5	0.5
Chlordane 60% E.C.	1.57	2.08	2.60
(Chlordane a.i.)	(0.94)	(1.25)	(1.56)
Total:	137.07	137.58	138.10

(2) Melamine:

Sample code	MA	MB	MC
Oshika resin PW-28	100 parts	100 parts	100 parts
Wheat flour	25	25	25
Water	10	10	10
NH_4Cl	0.5	0.5	0.5
Chlordane 60% E.C.	1.57	2.08	2.60
(Chlordane a.i.)	(0.94)	(1.25)	(1.56)
Total:	137.07	137.58	138.10

(3) Phenol:

Sample code	PA	PB	PC
Oshika resin D-18	100 parts	100 parts	100 parts
Hot P-5	4	4	4
Wheat flour	10	10	10
Chlordane 60% E.C.	1.32	1.75	2.20
(Chlordane a.i.)	(0.79)	(1.05)	(1.32)
Total:	115.32	115.75	116.2

2. *Process of sample preparation*

Thickness : 4 mm (final)
Composition : 0.75+2.7+0.75 mm, 3 plies
Wood species : Face and back, lauan 0.75 mm thick
Core, lauan 2.7 mm thick
Glue spread : 350 g/m^2 (32 g/900 cm^2)
Assembly time: less than 15 minutes
Cold press : room temperature, 10 kg/cm^2, 20 minutes
Storage : less than 30 minutes
Hot press : Urea—115°C, 10 kg/cm^2, 90 seconds
Melamin—125°C, 10 kg/cm^2, 90 seconds
Phenol—135°C, 10 kg/cm^2, 200 seconds

Every sheet was kept separately at room temperature for three hours for cooling. Samples were stored in a sealed polyethylene sack, for each resin lot and each dose lot.

3. Preparation of test sample

(1) For quantitative analysis three test pieces of 30 cm × 30 cm × 4 mm were taken from the indicated locations shown in Fig. 1 of the sample plywood. The three pieces consisted of two corners and one center piece. The corner pieces were taken out of more than 20 cm inside the edge of the sample. A sample piece of the plywood was cut as shown in Fig. 2 for the test. At first, the piece was cut into three equally sized small pieces, in which the fiber direction of those surface ply was parallel. α-1, α-2 and α-3 were given as the code numbers of those three small pieces. "α" was an individual name of the piece. α-1 and α-3 were used for the analysis and α-2 for the measuring of specific gravity.

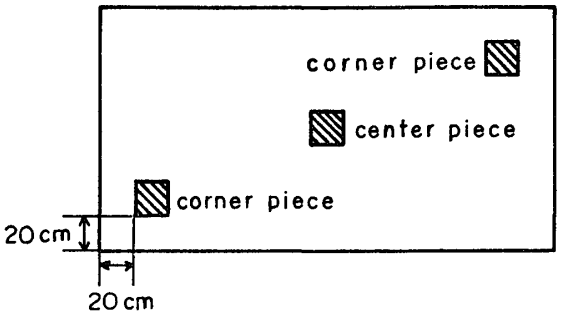

Fig. 1. Sampling of test pieces from three locations in plywood.

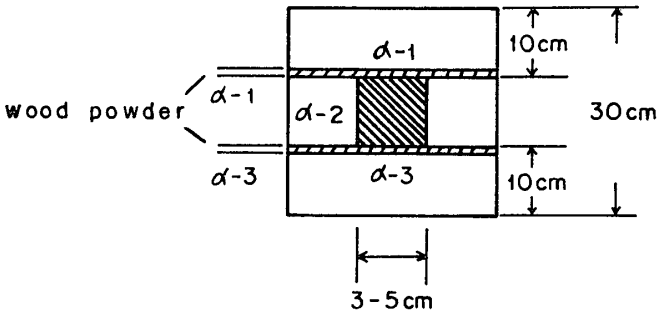

Fig. 2. Preparation of test sample (α-2) for specific gravity measurement.

The 3~5 cm wide piece was cut from the small piece α-2 and its volume and weight were measured. The specific gravity (D) of the plywood is given as follows:

$$\text{Specific gravity (D)} = \frac{\text{Weight of the piece (g)}}{\text{Volume of the piece (thickness} \times \text{width} \times \text{length)}}$$

(2) Test samples for quantitative analysis were taken as follows. The pieces α-1 and α-3 were fixed vertically on the flat and clean plate as shown in Fig. 3. The sound

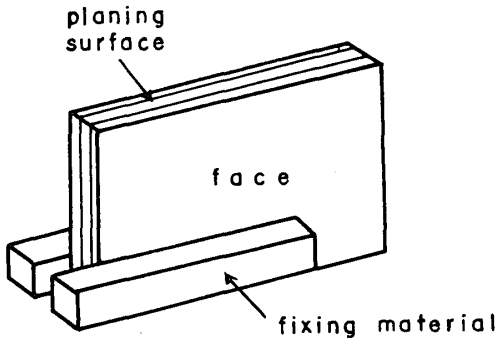

Fig. 3. Preparation of wood flakes for chlordane analysis from α-1 and α-3.

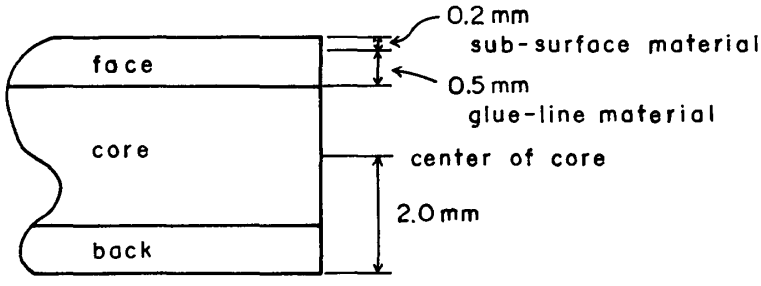

Fig. 4. Sampling of test piece for chlordane analysis.

part without nodes or slits was selected, and the part which had impurity such as gum tape keeping plies uncracked was excluded. First, these pieces were weighed and then shaved into wood flakes of approximately two grams with a sharp plane. Two grams sample included any and all fines produced during planing. Especially pulverized fines were collected carefully because the resin turned out to be very fine powder during planing process, and this powder gave great influence to the analytical results. The use of mechanical saw for the preparation of the wood powder was not suitable because it increased the loss of the fine powder. The gross parts of the collected fine wood particles were crushed with a coffee mill until it was broken down

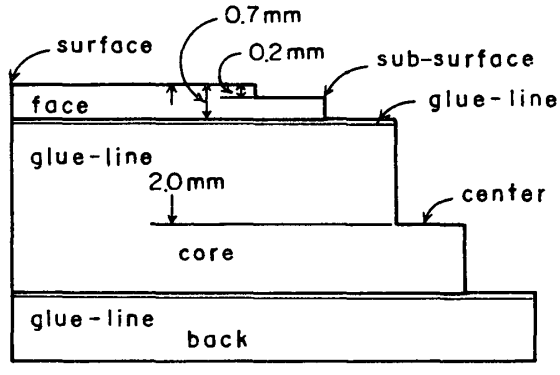

Fig. 5. Sampling of test piece for assaying insecticidal effect of chlordane.

to around 20 mesh size. Test pieces for quantitative analysis of determined lays were taken as shown in Fig. 4 and then powdered according to the above-mentioned method.

(3) Test pieces for bio-assay were prepared as Fig. 5. Bio-assay was carried out in surface, sub-surface, glue-line and center of each plywood.

4. Method of quantitative analysis

The wood powder prepared by this method was precisely weighed. A round-filter paper was filled with the wood powder and was set in a soxlet extracting apparatus. The wood powder was kept in benzene for an hour without agitation and then extracted for three hours under reflux. The extract was concentrated *in vacuo* at 40°C by an evaporator.

Since chlordane would be lost by complete evaporation of benzene, the evaporation was stopped just before completeness. After the benzene-evaporation process, 5 ml of diethanol amine reagent (designated in JAS 877) was added to the residue. The reaction mixture was heated in boiling water for 30 minutes and was cooled immediately in the cold water for 5 minutes. Methyl alcohol (guaranteed reagent) was added to the solution to make 25 ml for analysis.

The absorbance at 521 nm was measured for blank solution (5 ml of diethanolamine reagent and 20 ml of methyl alcohol mixed, total 25 ml) and standard

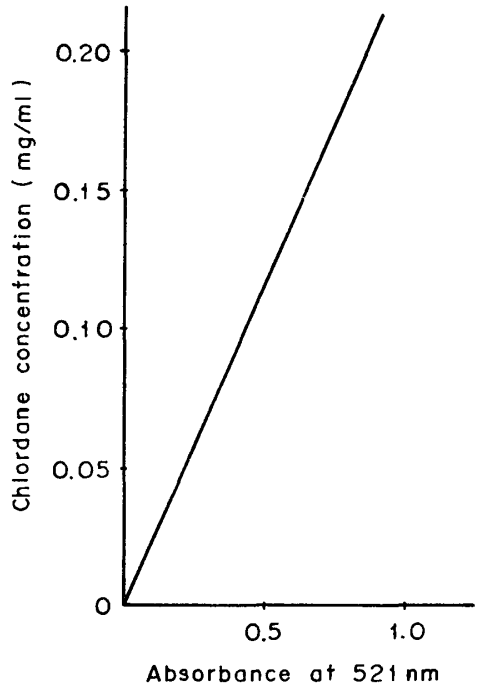

Fig. 6. Calibration curve of chlordane. Control solution: diethanolamine 5 ml+methyl alcohol 20 ml.

chlordane solution, and chlordane content in each sample was calculated from the calibration curve (Fig. 6).

Standard chlordane solution was prepared as follows. Methyl alcohol (guaranteed reagent) was added to 0.2 g of technical chlordane standard grade to make 100 ml of the original standard chlordane solution. Ten ml of the original standard chlordane solution was diluted with methyl alcohol to make 50 ml of standard chlordane solution.

Zero to 6 ml standard chlordane solution was taken and after methyl alcohol evaporated, 5ml of diethanolamine reagent was added. The solution was heated for 30 minutes in boiling water in a capless receipt and cooled immediately in cold water for 5 minutes. Methyl alcohol was added again to the residue to make 25 ml solution. The average of the results of quantitative analysis of the three test pieces was calculated as chlordane content. Two small parts, α-1 and α-3 from each test piece, were also tested together. Chlordane content in plywood was calculated as:

$$\text{Chlordane content } (\text{kg/m}^3) = \frac{\text{Chlordane weight (g) in analyzed sample}}{\text{Wood powder weight (air-dried, g)}} \times D \times R \times 1000$$

D: Specific gravity (air-dried) of plywood (average of three piece)

R: Specific factor set for each resin (resin factor)

R=3.5 for urea, urea melamine and PVAc resin adhesives.

R=4.5 for phenol resin adhesives.

5. Method of bio-assay

For the purpose of bio-assay, *Lyctus* beetle should be used, but the author has not been successful in rearing *Lyctus* continuously in his laboratory. Therefore, the adult of *Tribolium castaneum* HERBST was used as its substitute insect. Ten-day-old adults were used. Those were previously reared in the laboratory with wheat flour as food. Fifty adults were placed in a 4.0 cm diameter × 2.0 cm height glass ring fixed on the test wood piece and their health conditions were observed at regular intervals. Health conditions were expressed in Mortality (M), Knock-down (ND) and Healthy (H).

Results and Discussion

1. Results of quantitative analysis

The amounts of chlordane contained in total plywoods were shown in Table 1, and that of chlordane contained in each layer of plywood was shown in Table 2. Percentage of chlordane detection was highest in urea resin glue, followed by melamine and phenol. Since no special correlation was found between the amount of chlordane mixed with the glue and the percentage of its detection but they were

proportionate, its detection seemed to be affected by the type of resin to be mixed. While mechanism of chlordane diffusion into other layers from the glue-line during plywood manufacturing process was still not clear, there was a high probability of chlordane being diffused to other layers during piling after glue coating or during hot press operation. If this hypothesis was correct, it was natural that chlordane diffusion was affected by the type of resin. Since the analytical method of chlordane established by Velsicol Chemical Corporation and specified by JAS is based on extrac-

Table 1. The amounts of chlordane contained in total plywoods.

Sample*	A**	Chlordane Dosage g/m³	Test Piece No.	Amt. of Chlordane Detected		Detection %
				B***	g/m³	
UA	0.46	600	1	0.049	227	37.8
			2	0.042	195	32.4
			mean	0.046	211	35.1
UB	0.47	800	1	0.059	278	34.8
			2	0.057	269	33.6
			mean	0.058	274	34.2
UC	0.51	1000	1	0.076	391	39.1
			2	0.070	360	36.0
			mean	0.073	375	37.5
MA	0.52	600	1	0.038	199	33.2
			2	0.037	193	32.2
			mean	0.038	196	32.8
MB	0.55	800	1	0.047	258	32.3
			2	0.049	269	33.6
			mean	0.039	264	33.0
MC	0.53	1000	1	0.073	388	38.8
			2	0.058	308	30.8
			mean	0.066	348	34.8
PA	0.54	600	1	0.027	144	24.0
			2	0.031	166	27.7
			mean	0.029	155	25.9
PB	0.53	800	1	0.043	228	28.5
			2	0.041	218	27.2
			mean	0.042	223	27.9
PC	0.52	1000	1	0.046	241	24.1
			2	0.048	252	25.2
			mean	0.047	247	24.5

* See *Formula of glue.*
** Specific gravity of air-dried test piece.
*** Percentage against weight of air-dried test piece.

Table 2. The amounts of chlordane contained in each layer of plywoods.

Sample*	Layer	Depth from the Surface mm	A**	Chlordane Dosage g/m³	Amt. of Chlordane Detected		Ratio by Layer
					B***	g/m³	
UA	Surface	0 ~0.2	0.46	600	0.008	37	23
	Glue-line	0.2~0.7			0.035	162	100
	Center	0.7~2.0			0.023	107	66
	Total Plywood	0 ~4.0			0.046	211	—
UB	Surface	0 ~0.2	0.47	800	0.013	61	24
	Glue-line	0.2~0.7			0.053	251	100
	Center	0.7~2.0			0.030	139	55
	Total Plywood	0 ~4.0			0.058	274	—
UC	Surface	0 ~0.2	0.51	1000	0.015	77	22
	Glue-line	0.2~0.7			0.069	352	100
	Center	0.7~2.0			0.028	144	41
	Total Plywood	0 ~4.0			0.073	375	—

* See *Formula of glue.*
** Specific gravity of air-dired test piece.
*** Percentage against weight of air-dried test piece.

Table 3. Insecticidal effect of each layer of plywood (urea resin and 600g/m³ chlordane)

UA*	No.	8 hrs.	24 hrs.	32 hrs.	48 hrs.	72 hrs.	80 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0-0-50	—	2-13-35	—	—	—
	2	0-0-50	0-0-50	—	3-11-36	—	—	—
	3	0-0-50	3-4-43	—	10- 7-33	—	—	—
	4	0-0-50	0-7-43	—	6-10-34	—	—	—
	Av.	0-0-50	1-3-46	—	5-10-35	—	—	—
Sub-surface	1	0-0-50	0-0-50	0-0-50	2- 4-44	5-10-35	6- 7-37	9-16-25
	2	0-0-50	0-0-50	0-0-50	2- 1-47	6- 1-43	7- 2-41	10-15-25
	3	0-0-50	0-0-50	0-0-50	1- 1-48	3- 4-43	6-11-33	9-16-25
	4	0-0-50	0-0-50	0-0-50	0- 2-48	4- 5-41	5- 6-39	9-13-28
	Av.	0-0-50	0-0-50	0-0-50	1- 2-47	4- 5-41	6- 7-37	9-15-26
Center	1	0-0-50	5-5-40	—	6-20-24	—	—	—
	2	0-0-50	1-2-47	—	5- 7-38	—	—	—
	3	0-0-50	7-2-41	—	10-15-25	—	—	—
	4	0-0-50	4-3-43	—	6-13-31	—	—	—
	Av.	0-0-50	4-3-43	—	7-14-29	—	—	—
Glue-line	1	0-0-50	0-0-50	0-1-49	0- 5-45	3-15-32	5-18-27	18-12-20
	2	0-0-50	0-3-47	0-6-44	3-16-31	6-25-19	11-22-17	23-17-10
	3	0-0-50	0-0-50	1-4-45	4- 3-43	7- 8-35	7-10-33	11-14-25
	4	0-0-50	0-2-48	0-5-45	1-10-39	4-17-29	5-22-23	19-22- 9
	Av.	0-0-50	0-1-49	0-4-46	2- 8-40	5-16-29	7-18-25	18-16-16

* See *Formula of glue.*
** M: Mortality, ND: Knock-down H: Healthy.
These remark's are the same in Tables 4~11.

Table 4. Insecticidal effect of each layer of plywood (urea resin and 800 g/m³ chlordane)

UB*	No.	8 hrs.	24 hrs.	32 hrs.	48 hrs.	72 hrs.	80 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0-0-50	—	7- 6-37	—	—	—
	2	0-0-50	1-1-48	—	4-10-36	—	—	—
	3	0-0-50	0-2-48	—	7-10-33	—	—	—
	4	0-0-50	0-9-41	—	5-17-28	—	—	—
	Av.	0-0-50	0-3-47	—	5-11-34	—	—	—
Sub-surface	1	0-0-50	1-0-49	1-0-49	2- 4-44	3- 5-42	4- 9-37	5-16-29
	2	0-0-50	0-1-49	0-4-46	0-11-39	3-12-35	6-12-32	9-18-23
	3	0-0-50	0-0-50	0-2-48	1- 8-41	3-15-32	6-16-28	10-19-21
	4	0-0-50	0-0-50	0-2-48	0-18-32	10-17-23	15-19-16	18-23- 9
	Av.	0-0-50	0-0-50	0-2-48	1-10-39	5-12-33	8-14-28	10-19-21
Center	1	0-0-50	5-3-42	—	8-16-26	—	—	—
	2	0-0-50	4-2-44	—	9-14-27	—	—	—
	3	0-0-50	5-2-43	—	8-11-31	—	—	—
	4	0-0-50	5-4-41	—	10-17-23	—	—	—
	Av.	0-0-50	5-3-42	—	9-15-26	—	—	—
Glue-line	1	0-0-50	0-2-48	1-5-44	5-15-30	15-17-18	15-20-15	24-21- 5
	2	0-0-50	0-1-49	0-7-43	0-17-33	8-30-12	15-24-11	25-19- 6
	3	0-0-50	0-2-48	0-6-44	1-15-34	10-19-21	15-16-19	20-27- 3
	4	0-0-50	0-2-48	0-6-44	3-10-37	8-21-21	11-23-16	17-25- 8
	Av.	0-0-50	0-2-48	0-6-44	2-14-34	10-22-18	15-22-13	21-23- 6

Table 5. Insecticidal effect of each layer of plywood (urea resin and 1000 g/m³ chlordane)

UC*	No.	8 hrs.	24 hrs.	32 hrs.	48 hrs.	72 hrs.	80 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	1- 1-48	—	5- 2-43	—	—	—
	2	0-0-50	1- 0-49	—	5- 8-37	—	—	—
	3	0-0-50	2- 8-40	—	1-15-34	—	—	—
	4	0-0-50	0-10-40	—	9-16-25	—	—	—
	Av.	0-0-50	1- 5-44	—	5-10-35	—	—	—
Sub-surface	1	0-0-50	0- 0-50	0- 2-48	1-13-36	7-17-26	10-15-25	13-26-11
	2	0-0-50	0- 1-49	0- 2-48	4-10-36	9-13-28	17- 7-26	22-12-16
	3	0-0-50	0- 2-48	2- 0-48	3- 4-43	9-12-29	9-12-29	13-18-19
	4	0-0-50	0- 0-50	0- 2-48	0- 8-42	3-11-36	5-15-30	8-23-19
	Av.	0-0-50	0- 1-49	0- 2-48	2- 9-39	7-13-30	10-13-27	14-20-16
Center	1	0-0-50	7- 3-40	—	15-15-20	—	—	—
	2	0-0-50	2- 7-41	—	8-23-19	—	—	—
	3	0-0-50	3- 3-44	—	12-20-18	—	—	—
	4	0-0-50	4- 6-40	—	11-20-19	—	—	—
	Av.	0-0-50	4- 5-41	—	12-19-19	—	—	—
Glue-line	1	0-0-50	0-18-32	0-29-21	14-30- 6	26-23- 1	33-17- 0	44- 6- 0
	2	0-0-50	0-17-33	0-24-26	10-36- 4	24-26- 0	30-20- 0	33-17- 0
	3	0-0-50	0-11-39	0-18-32	7-40- 3	15-35- 0	17-33- 0	28-22- 0
	4	0-0-50	0-16-34	3-24-23	9-40- 1	12-37- 1	41- 9- 0	46- 4- 0
	Av.	0-0-50	0-16-34	1-24-25	10-37- 3	18-31- 1	30-20- 0	38-12- 0

Table 6. Insecticidal effect of each layer of plywood (melamine resin and 600 g/m³ chlordane)

MA*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	1-1-48	2-10-38	—	—
	2	0-0-50	0-1-49	3-11-36	—	—
	3	0-0-50	0-1-49	2- 5-43	—	—
	4	0-0-50	0-1-49	3-10-37	—	—
	Av.	0-0-50	0-1-49	3- 9-38	—	—
Sub-surface	1	0-0-50	2-1-47	3-17-30	—	—
	2	0-0-50	2-0-48	2-10-38	—	—
	3	0-0-50	3-0-47	5-12-33	—	—
	4	0-0-50	2-2-46	4-10-36	—	—
	Av.	0-0-50	2-1-47	4-12-34	—	—
Center	1	0-0-50	0-2-48	2-12-36	4-27-19	12-30-8
	2	0-0-50	0-6-44	3-21-26	8-32-10	21-27-2
	3	0-0-50	0-8-42	5-18-27	4-30-16	15-31-4
	4	0-0-50	0-7-43	5-20-25	4-30-16	19-25-6
	Av.	0-0-50	0-6-44	4-18-28	5-30-15	17-28-5
Glue-line	1	0-0-50	0-9-41	19-23- 8	37- 7- 6	41- 5-4
	2	0-0-50	3-8-39	14-20-16	32-10- 8	36- 9-5
	3	0-0-50	1-4-45	10-31- 9	33- 9- 8	35-10-5
	4	0-0-50	1-6-43	13-26-11	33-11- 6	38- 7-5
	Av.	0-0-50	1-7-42	14-25-11	34- 9- 7	37- 8-5

Table 7. Insecticidal effect of each layer of plywood (melamine resin and 800 g/m³ chlordane)

MB*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0- 0-50	3- 8-39	—	—
	2	0-0-50	1- 0-49	6- 6-38	—	—
	3	0-0-50	2- 1-47	7- 7-36	—	—
	4	0-0-50	2- 4-44	4-10-36	—	—
	Av.	0-0-50	1- 1-48	5- 8-37	—	—
Sub-surface	1	0-0-50	2- 8-40	4-16-30	—	—
	2	0-0-50	1- 2-47	3-20-27	—	—
	3	0-0-50	2- 6-42	8-18-24	—	—
	4	0-0-50	3- 7-40	6-17-27	—	—
	Av.	0-0-50	2- 6-42	5-18-27	—	—
Center	1	0-0-50	0- 9-41	2-26-22	18-25-7	27-22-1
	2	0-0-50	0- 8-42	2-34-14	8-41-1	25-25-0
	3	0-0-50	1-10-39	7-23-20	11-36-3	23-27-0
	4	0-0-50	3- 9-38	5-33-12	15-30-5	30-20-0
	Av.	0-0-50	1- 9-40	4-29-17	13-33-4	26-24-0
Glue-line	1	0-0-50	0-16-34	19-25- 6	33-15-2	41- 7-2
	2	0-0-50	2-16-32	15-23-12	27-20-3	37-12-0
	3	0-0-50	1-15-34	16-29- 5	34-16-0	42- 8-0
	4	0-0-50	1-16-33	16-26- 8	29-18-3	39- 9-2
	Av.	0-0-50	1-16-33	17-26- 7	31-17-2	40- 9-1

Table 8. Insecticidal effect of each layer of plywood (melamine resin and 1000g/m³ chlordane)

MC*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	4- 2-44	8-15-27	—	—
	2	0-0-50	3- 1-46	5-13-32	—	—
	3	0-0-50	4- 3-43	11-10-29	—	—
	4	0-0-50	4- 4-42	5-11-34	—	—
	Av.	0-0-50	4- 3-43	7-12-31	—	—
Sub-surface	1	0-0-50	0-12-38	0-35-15	—	—
	2	0-0-50	0-11-39	5-24-21	—	—
	3	0-0-50	2-13-35	5-27-18	—	—
	4	0-0-50	4-12-34	7-26-17	—	—
	Av.	0-0-50	2-12-36	4-28-18	—	—
Center	1	0-0-50	0-12-38	9-23-18	18-31-1	33-17-0
	2	0-0-50	0-15-35	5-29-16	15-34-1	20-30-0
	3	0-0-50	2-18-30	8-29-13	18-30-2	27-23-0
	4	0-0-50	5-14-31	9-26-15	14-34-2	26-24-0
	Av.	0-0-50	2-15-33	8-27-15	16-32-2	26-24-0
Glue-line	1	0-0-50	0-19-31	14-29- 7	34-15-1	42- 7-1
	2	0-0-50	0-19-31	12-32- 6	25-21-4	37-12-1
	3	0-0-50	0-15-35	14-27- 9	29-16-5	34-15-1
	4	0-0-50	0-19-31	12-29- 9	31-17-2	39-10-1
	Av.	0-0-50	0-18-32	13-29- 8	30-17-3	38-11-1

Table 9. Insecticidal effect of each layer of plywood (phenol resin and 600 g/m³ chlordane)

PA*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0- 0-50	0- 0-50	0- 0-50	2- 0-48
	2	0-0-50	0- 0-50	0- 0-50	0- 0-50	1- 0-49
	3	0-0-50	0- 0-50	0- 0-50	0- 0-50	1- 0-49
	4	0-0-50	0- 0-50	0- 0-50	0- 0-50	1- 0-49
	Av.	0-0-50	0- 0-50	0- 0-50	0- 0-50	1- 0-49
Sub-surface	1	0-0-50	0- 0-50	0- 0-50	0- 1-49	2- 2-46
	2	0-0-50	0- 0-50	0- 0-50	1- 2-47	4- 3-43
	3	0-0-50	0- 0-50	0- 0-50	1- 1-48	5- 3-42
	4	0-0-50	0- 0-50	0- 0-50	1- 2-47	2- 4-44
	Av.	0-0-50	0- 0-50	0- 0-50	1- 2-47	3- 3-44
Center	1	0-0-50	0- 9-41	3-13-33	11-21-18	16-26- 8
	2	0-0-50	0- 3-47	3-10-37	8-27-15	18-23- 9
	3	0-0-50	0- 5-45	4-10-36	10-23-17	18-22-10
	4	0-0-50	0- 7-43	4-14-32	10-24-16	17-26- 7
	Av.	0-0-50	0- 6-44	4-12-34	10-23-17	17-24- 9
Glue-line	1	0-0-50	0- 8-42	11-17-22	22-18-10	28-15- 7
	2	0-0-50	2- 7-41	9-22-19	26-15- 9	33-15- 2
	3	0-0-50	0-13-37	9-26-15	27-16- 7	33-14- 3
	Av.	0-0-50	1- 9-40	10-22- 8	25-16- 9	31-15- 4

Table 10. Insecticidal effect of each layer of plywood (phenol resin and 800 g/m³ chlordane)

PB*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0-0-50	0- 0-50	2- 0-48	4- 2-44
	2	0-0-50	0-0-50	0- 0-50	0- 0-50	1- 1-48
	3	0-0-50	0-0-50	0- 0-50	1- 0-49	2- 2-46
	4	0-0-50	0-0-50	0- 0-50	1- 0-49	1- 1-48
	Av.	0-0-50	0-0-50	0- 0-50	1- 0-49	2- 2-46
Sub-surface	1	0-0-50	0-0-50	0- 0-50	1- 2-47	2- 1-47
	2	0-0-50	0-0-50	0- 2-48	1- 4-45	4- 5-41
	3	0-0-50	0-0-50	0- 2-48	2- 2-46	3- 2-45
	4	0-0-50	0-0-50	0- 1-49	1- 3-46	3- 4-43
	Av.	0-0-50	0-0-50	0- 1-49	1- 3-46	3- 3-44
Center	1	0-0-50	0-8-42	4-17-29	13-25-12	20-24- 6
	2	0-0-50	0-7-43	3-14-33	7-22-21	15-32- 3
	3	0-0-50	0-7-43	5-15-30	11-23-16	19-26- 5
	4	0-0-50	0-9-41	2-20-28	11-26-13	16-29- 5
	Av.	0-0-50	0-8-42	4-17-29	11-24-15	17-28- 5
Glue-line	1	0-0-50	0-0-50	0-25-25	11-27-12	31-15- 4
	2	0-0-50	0-6-44	8-20-22	20-22- 8	33-11- 6
	3	0-0-50	2-3-45	9-17-24	23-19- 8	34-10- 6
	Av.	0-0-50	1-3-46	6-21-23	18-23- 9	33-12- 5

Table 11. Insecticidal effect of each layer of plywood (phenol resin and 1000 g/m³ chlordane)

PC*	No.	8 hrs.	24 hrs.	48 hrs.	72 hrs.	96 hrs.
		M-ND-H**	M-ND-H	M-ND-H	M-ND-H	M-ND-H
Surface	1	0-0-50	0- 0-50	0- 3-47	1- 8-41	3- 7-40
	2	0-0-50	0- 0-50	1- 2-47	3- 5-42	4- 8-38
	3	0-0-50	0- 0-50	1- 3-46	3- 7-40	4-10-36
	4	0-0-50	0- 0-50	1- 4-45	2- 4-44	4- 4-42
	Av.	0-0-50	0- 0-50	1- 3-46	2- 6-42	4- 7-39
Sub-surface	1	0-0-50	0- 0-50	0- 3-47	1- 6-44	2-10-38
	2	0-0-50	0- 0-50	0- 0-50	1- 2-47	1- 4-45
	3	0-0-50	0- 0-50	0- 4-46	3- 4-43	3- 9-38
	4	0-0-50	0- 0-50	0- 5-45	2- 6-42	6-12-32
	Av.	0-0-50	0- 0-50	0- 3-47	2- 5-43	3- 9-38
Center	1	0-0-50	0-15-35	4-26-20	12-37- 1	28-22- 0
	2	0-0-50	0-18-32	5-34-11	9-39- 2	24-25- 1
	3	0-0-50	0-16-34	4-31-15	10-39- 1	27-23- 0
	4	0-0-50	0-16-34	4-28-18	8-39- 3	26-24- 0
	Av.	0-0-50	0-16-34	4-30-16	10-38- 2	26-24- 0
Glue-line	1	0-0-50	0-26-24	12-32- 6	23-23- 4	36-12- 2
	2	0-0-50	0-27-23	16-30- 4	29-20- 1	43- 7- 0
	3	0-0-50	3-26-21	18-26- 6	32-16- 2	43- 6- 1
	Av.	0-0-50	1-26-23	15-29- 6	28-20- 2	41- 8- 1

tion of the compound from the wood by solvent, if chlordane was captured fixed in the glue-line, the total amount of chlordane retained in the entire plywood was not necessarily extractable, and that the extracted amount might be limited only to that diffused in other layers than the glue-line. In the case that pulverized thermoset film of glue containing chlordane was extracted and analyzed,20 to 25% was detected. Thus, it was found to be extremely difficult to extract chlordane once captured in the glue-line.

According to the analytical result in each layer, detection from the glue-line layer was highest, followed by the center and the surface. Making the glue-line layer 100, surface was 22~24, and the center 41~66. It was found a trend that the more chlordane was added, the more was detected around the glue-line layer.

2. *Results of bio-assay*

Results of biological tests per type of resin were shown in Table 3–11. When the plywood is infested by *Lyctus*, the adult lays eggs in the sub-surface. Since eggs are supposed to be placed at about 0.5 mm from the surface, sufficient insecticidal affect may be expected providing lethal dose is available between the sub-surface and the glue-line. Reviewing the test results from the above standpoint, health conditions of furnished insect on the sub-surface and the glue-line face should be considered as an important criteria of efficacy judgement.

Provided all other conditions were the same, there was a slight difference of effect depending upon the type of resin. In general, efficacy was highest in melamine resin glue, and that in urea and phenol resins was more or less similar. Although it is natural that chlordane efficacy is increased in proportion to the amount of mixture, this trend was phenomenal on the glue-line face. In case of urea resin adhesive on the surface, there was no appreciable difference of effect depending upon the amount of chlordane to be mixed, which there was a slight reduction of efficacy at 600 g/m^3 level. On the glue-line face, there was a definite correlation between efficacy and the amount of mixture. On the center face, 1000 g/m^3 showed statistical significance over the other two doses.

Conclusion

As the result of the experiment of determining distribution of chlordane in the plywood and its insecticidal effect by using samples of the plywood in which glue-line chlordane was mixed, the following conclusion was obtained.

1. According to the quantitative method of analysis based on solvent extraction, only 30~40% chlordane was detected out of the plywood. This method should be improved in future.
2. Distribution ratio of chlordane in the plywood was found to be 100 in the glue-

line, 50 in the center and 20 in the surface. The more chlordane was added, the more it was captured in the glue-line.

3. Insecticidal effect of chlordane on the surface of the plywood was found to be quite low regardless the amount of its mixture, but judging from the way of *Lyctus* infestation, its effect on and below the sub-surface was considered to be more important.

4. Effective does of chlordane in each layer of the plywood, although a slight difference was found depending upon the type of resin used, was 600 g/m^3 on the glue-line, 800 g/m^3 on the center face and 1000 g/m^3 on the sub-surface. In order to expect workable effect on the surface, probably more than 1000 g/m^3 of chlordane should be mixed.

5. It was evident that there was definite correlation between the amount of chlordane distribution in the plywood and its insecticidal effect.

6. In order to expect long residual effect, 900 to 1000 g/m^3 was required for glue-line mixture.

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